DOWNHOLE TOOL

FIELD OF THE INVENTION

This invention relates to a downhole tool, and embodiments of the invention relate to a flow-actuated downhole tool, most typically a bypass tool.

BACKGROUND OF THE INVENTION

In the oil and gas industry, bores are drilled from surface to access subsurface hydrocarbon-bearing formations. In such a drilling operation, a drill bit is mounted on the end of a long "string" of pipe sections, and may be rotated from surface or by a motor located adjacent the drill bit. Drilling fluid or "mud" is pumped from surface down through the tubular string, to exit the drill bit via jetting nozzles. The drilling fluid then passes back to surface via the annulus between the drill pipe string and the bore wall. The drilling fluid serves a number of purposes, one being to carry drill cuttings away from the drill bit and then up through the annulus to surface, another being to hold the fluid in the rock back from flowing into the well.

A bypass tool is a tubular part of the drillstring that has one or more ports in its sidewall allowing fluid to flow directly out into the annulus of the well. In doing so the fluid bypasses the string below the tool. If the string throughbore below the ports is blocked then all the flow will pass out of the ports. If the throughbore is not blocked a proportion of the flow will continue onward through the bottom hole assembly (BHA) at the end of the string and out of the drill bit via the jetting nozzles.

There are two main reasons for wanting to open the ports in a bypass tool. The first is to improve the cleaning effect of the mud on the cuttings in the annulus; bypassing relieves pressure thereby reducing the work that the pump has to do, allowing the pumping rate to be increased. The second major reason is to prevent mud flow going through the BHA and drill bit. The most common reason for this is when pumping lost-circulation material (LCM). LCM consists of various sized solid particles suspended in the mud. LCM is required when the mud is being lost down hole; the mud drains away into a surrounding porous formation, rather than returning to surface. An LCM "pill" is pumped down the hole to plug the pores in the formation. However, if fine LCM will not cure the losses, coarse LCM must be used. In this case a bypass tool must be used to prevent the LCM going through the BHA and bit, as the LCM would likely plug the string at this point.

The conventional way to operate a bypass tool is to pump a ball down the string. This blocks off the through bore and allows the ports to be opened. Some tools (see, for example Lee, US 4,889,199) allow one ball to block off the through bore and open up the side ports and another ball to reverse the process; this can be repeated several times. However, this process is time consuming and it would be preferable to achieve the same result using flow alone; to function a tool using a ball typically takes about an hour because the ball must be pumped into place with some care. By contrast, using flow to actuate the tool may only take a few seconds. There have been numerous proposals relating to flow activated bypass tools. However, flow activated bypass tools are not commonly used and are never used for pumping LCM. Although recognised as being highly desirable it has proved very difficult to make a robust and reliable flow activated bypass tool and particularly one that can divert all the flow out of the side ports.

The majority of prior proposals for flow activated bypass tools have a spring which tends to move a valve sleeve to shut the side ports, that is the tool is normally closed. To the driller this would appear to be the natural orientation for the spring for many good well control reasons. One of these reasons would be that if the ports were by default shut, gas would be prevented from percolating inside the pipe where it could expand and travel up the string, causing a blow out. Although unlikely this is not a risk drillers like to take.

The applicant has noted that there are some significant disadvantages to using a normally closed spring-loaded flow activated bypass tool. Firstly, as the tool sleeve moves back and forth, it is possible that the sleeve will eventually jam. In this case the sleeve is more likely to jam open, as the sleeve-opening flow-generated forces experienced by the tool are substantially greater than the closing spring force. This would constitute a failure requiring the whole drill string to be pulled out of hole. Secondly, if it is desired to block the throughbore just below the ports in order to spot LCM it would be difficult of avoid the blocking mechanism taking the form of a flow restriction which interacts with the valve sleeve to provide a valve opening force. When the side ports were shut all the flow would go past the flow restriction creating a significant opening force. However, once the ports were open none of the flow would go past the flow restriction and there would be very little opening force, such that the spring would tend to close the ports. Thus the tool would be unstable and would reciprocate open and closed. This shuttling of the valve sleeve would likely damage the seals and thus the tool would be of no practical use for spotting LCM. Finally, if the blockage of the through bore were further downstream from the ports such that the flow restriction was isolated from the bypass sleeve, a sump would be left between the side ports and the throughbore blockage. In use, LCM would settle

here temporarily, until the ports were closed and the restriction opened, when the LCM in the sump would be pumped down through the BHA. This is clearly undesirable.

Accordingly it is amongst the objectives of the embodiments of the present invention to provide an improved flow activated bypass tool capable of spotting LCM, enhanced cutting removal and better mud drainage from the pipe as the pipe is pulled from the well, while minimising the well control risks.

SUMMARY OF THE INVENTION

According to the present invention there is provided a downhole tool comprising a body defining a bore and having a valve arrangement including a flow port in the wall of the body and a valve element biased towards a position to open the port, the valve element being initially releasably retained in a position to close the flow port.

According to another aspect of the present invention there is provided a method of providing bypass in a drill string, the method comprising:

providing a tool in a drill string, the tool comprising a body defining a bore and having a valve arrangement including a flow port in the wall of the body and a valve element biased towards a position to open the port;

retaining the valve element in a position to close the flow port; and then

releasing the valve element such that the valve element moves to open the flow port.

Tools made in accordance with the present invention may be useful in many situations, including as a bypass tool or as a dump sub. The tool is primarily intended for use in drilling applications, and accordingly may be adapted to be incorporated in

a drill string. However, the tool may be utilised in other downhole operations, and may also have utility in surface and subsea applications.

The valve element may be initially retained in the closed position by a retaining arrangement of any appropriate form, including a shear member, such as a shear pin or ring. In other embodiments the retaining arrangement may be retractable or reconfigurable to a release configuration, and may take the form of a sprung retainer or a cam arrangement.

Preferably, the tool further comprises a valve element release arrangement. This may take the form of a member adapted to be selectively located in the body. Thus, in one embodiment, a member may be dropped or pumped from surface to travel down through the string to land on the body. The member may be adapted to release the valve element simply by engaging the body. For example, the member may be configured to engage with and release a valve element retaining arrangement. In other embodiments the member may permit application of a flow-induced force to a valve element retaining arrangement, for example the member may define a flow restriction, allowing a flow-induced force to be utilised to shear a retaining pin. In one embodiment the member comprises a sleeve. The member may be adapted to land on the body above or below the flow port.

Preferably, the tool further comprises a body bore restriction. The restriction may be incorporated in the tool body, but is preferably a separate element which may be located in the body when required. The restriction may be dropped or pumped from surface. The restriction may be adapted to completely close the bore, or may permit flow through the bore. Preferably, the restriction is adapted for location below the flow port, to facilitate redirection of at least a proportion of flow through the flow port. Most preferably, the restriction is configurable to provide different degrees of

flow restriction. In a preferred embodiment, the restriction is configurable to close the body bore and to permit flow through the bore. The restriction may be biased to assume the closed configuration. The restriction may thus be utilised to prevent flow below the tool, which may be useful if the tool is used to spot LCM. Preferably, the restriction is adapted to be moved to the open configuration by fluid pressure. In one embodiment the restriction includes a fluid pressure actuated valve element, which element may be responsive to differential pressure thereacross.

Preferably, the restriction is locatable in the body directly below the flow port. In a preferred embodiment this ensures that, when the flow port is open, there is no sump of liquid below the flow port in which, for example, LCM can accumulate.

The restriction may further function as a valve element release.

Preferably, the tool further comprises a valve closing arrangement adapted for use in moving the valve element to close the flow port. The arrangement may be integral with the body but is preferably a separate element which may be located in the body when required, for example by dropping or pumping from surface. The arrangement may be retrievable. Preferably, the arrangement defines a flow restriction, whereby a flow-induced force may be applied to the valve member to close the flow port. The flow restriction may be fixed, or may be variable, that is the flow restriction may open as flow through the restriction increases. Preferably, the flow restriction is adapted for location above the flow port.

The valve closing arrangement may be selectively coupled to the valve element, for example by means of a cam arrangement. Such an arrangement allows forces to be applied to the valve closing arrangement, for example flow-induced forces, without the valve element being moved to close the port. Alternatively, or in

addition, the valve element may be selectively coupled to the valve body, for example by a cam arrangement, to control the movement of the valve element in response to flow-induced forces.

The valve closing arrangement may further serve as a valve element release.

The tool may further comprise an arrangement for locking the valve element in a position to close the flow port. Thus, after the flow port has been opened, it is possible to lock the flow port closed. The locking arrangement may be integral with the body, but is preferably in the form of a separate element adapted to be dropped or pumped from surface to land on the body, and may be in the form of a sleeve. The element may be adapted to lock the valve element relative to the body.

Preferably, the valve element is in the form of a sleeve.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the drawings will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1a is a sectional view of a downhole tool in accordance with a preferred embodiment of the present invention, the tool being shown in an initial configuration;

Figure 1b is a sectional view of a body bore restriction for use in combination with the tool of Figure 1a;

Figure 1c is a sectional view of a valve closing flow restriction for use in combination with the tool of Figure 1a;

Figure 1d is a sectional view on line D-D of Figure 1a;

Figure 2 is a sectional view of the tool of Figure 1a in a first configuration after the restriction of Figure 1b has landed on the tool;

Figure 3 shows the tool and restriction of Figure 2 in a second configuration;

Figure 4 is a sectional view of the tool and restriction of Figure 2 after the valve closing restriction of Figure 1c has landed on the tool;

Figure 5 shows the tool and restrictions of Figure 4 in a further configuration;

Figure 6 is a sectional view of the tool and restriction of Figures 1a and 1c in combination with an alternative body bore restriction;

Figure 7 shows the tool and restrictions of Figure 6 after a valve locking sleeve has landed on the tool;

Figure 8a is a sectional view of a downhole tool in accordance with an alternative embodiment of the present invention; and

Figure 8b is a representation of a cam track of the tool of Figure 8a.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is first made to Figure 1a of the drawings, which is a sectional view of a downhole tool, in the form of a bypass tool 10, in accordance with a preferred embodiment of the present invention. The tool 10 has a generally cylindrical body 12 which is intended to be incorporated in a drill string. Accordingly, the body 12 includes appropriate pin and box connections 14, 15, to allow the body 12 to be coupled to adjacent drill pipe sections. The body wall 16 defines a number of radially extending flow ports 18 which, in use, may be opened to permit fluid communication between the body bore 20 and the annulus between the body 12 and the surrounding bore wall (not shown). In an initial tool configuration, as shown in Figure 1a, a valve sleeve 22 closes the flow ports 18. Seals 24, 25 are provided on the sleeve 22 and are initially positioned on either side of the body wall flow ports 18 to prevent passage of fluid between the tool bore 20 and the annulus. As will be described, the sleeve 22 is movable to a position in which ports 26 in the sleeve 22 are aligned with the flow

ports 18, allowing fluid communication between the bore 20 and the annulus. The valve sleeve 22 is biased towards this open configuration by a compression spring 28 which acts between a shoulder in the body wall and a shoulder on the sleeve 22. However, the sleeve 22 is initially retained in the closed position by sprung pins 32 which extend from the sleeve 22 into corresponding recesses 34 in the body wall 16. The pins 32 are shown in greater detail in Figure 1d of the drawings, which is a sectional view on line D – D of Figure 1a. It will be noted that four radially extending retaining pins 32 are provided, each pin 32 being coupled, by a sleeve-mounted toggle 40, to a release pin 36 extending into the sleeve bore 38. Thus, when the release pins 36 are pushed radially outwardly the sprung pins 32 are retracted, allowing the spring 28 to move the sleeve 22 to align the ports 26, 18.

In this embodiment the release of the valve sleeve 22 is achieved by dropping a body bore restriction 42 into the tool. The restriction 42 is shown in Figure 1b of the drawings, and Figure 2 of the drawings shows the restriction 42 after it has landed in the sleeve 22. The restriction 42 comprises a tubular body 44 dimensioned to fit within the lower portion of the valve sleeve 22, and has an upper shoulder 46 which, when the restriction 42 lands on the sleeve 22, engages the inner ends of the release pins 36.

The restriction 42 includes a valve element 48 which is axially movable within the body 44 but is normally biased, by spring 52, to close the restriction body bore 50, as illustrated in Figure 1b. However, when the restriction 42 experiences a predetermined differential pressure the spring 52 will compress, allowing the valve element 48 to move downwardly and allowing fluid to flow past the restriction 42, as illustrated in Figure 2.

Reference is now also made to Figure 1c of the drawings, which illustrates a valve closing restriction 60 in the form of a sleeve 62 fitted with a choke 64. As will be described, the restriction 60 may be pumped into the pipe string to land on the sleeve 22, as illustrated in Figure 4 of the drawings, to allow the sleeve 22 to be returned to the closed position, following the release of the sleeve 22 by the restriction 42.

In use, the tool 10 will be run into a bore, within a drill string, in a configuration as illustrated in Figure 1a, that is with the sleeve 22 retained in the closed position, and without the restrictions 42, 60. In this configuration the tool 10 is inactive, allowing drilling operations to continue as normal, that is drilling fluid simply passes through the tool 10 from surface towards the BHA. However, when it is desired to open the tool 10, to provide fluid bypass, the body bore restriction 42 is inserted into the pipe string at surface and pumped down through the string until the restriction 42 lands on the sleeve 22, as illustrated in Figure 2. As described above, the valve element 48 normally closes the restriction bore 50. However, the momentum of the fluid following the restriction 42 will be such that the valve element 48 is moved to the open position on the restriction 42 landing on the sleeve 22.

When the restriction 42 lands on the sleeve 22, the sleeve release pins 36 will be pushed outwardly by the shoulder 46, causing the sprung retaining pins 32 to retract. However, the flow of fluid through the string, and through the restriction 42, will create a sufficient differential pressure force across the restriction 42 to retain the spring 28 in the compressed state and thus maintain the sleeve 22 in the closed position.

If however the operator then shuts off the drilling fluid pumps, the spring 52 will move the valve element 48 upwardly to close the restriction bore 50, and also the

spring 28 will lift the valve sleeve 22 to align the ports 18, 26, such that the tool 10 assumes a configuration as illustrated in Figure 3 of the drawings. It should be noted that while the valve element 48 closes the restriction bore 50, the element 48 is not intended to provide a fluid-tight seal with the body 44. This allows equalisation of pressure over the closed restriction 42, and thus avoids the possibility of a pressure lock across the restriction 42 which might otherwise cause the sleeve 22 to be locked in the closed position if the spring 52 caused the restriction 42 to close before the spring 28 had lifted the sleeve 22 and aligned the ports 18, 26.

When the pumps are restarted, the drilling fluid will pass down through the string and will then pass through the flow ports 18, 26 directly into the annulus, without passing through the part of the string below the tool 10. It will be noted from Figure 3 that, with the sleeve 22 in the open position, the upper end of the restriction 42 is aligned with the base of the flow ports 18. Thus, there is no sump of fluid below the ports 18.

As fluid may pass from the tool bore 20 through the open flow ports 18, it is difficult if not impossible to generate any substantive differential pressure across the restriction 42 with the tool 10 in this configuration. Accordingly, in normal operation, and even when pumping fluid at a relatively high rate, the tool 10 and restriction 42 will remain in the configuration as illustrated in Figure 3, until the restriction 60 is located in the tool 10. As noted above, the restriction 60 is adapted to be pumped through the string and land on the upper end of the sleeve 22, as illustrated in Figure 4 of the drawings. Pumping fluid through the restriction 60 leads to the creation of a substantial differential pressure across the choke 64. This force will tend to move the valve sleeve 22 downwardly and thus move the flow ports 18, 26 out of alignment, increasing the pressure within the body bore 20 and thus increasing the pressure

differential across the restriction 42. At some point, the differential pressure across the restriction 42 will be sufficient to open the valve element 48. Thus, the presence of the restriction 60 in the tool 10 allows the tool 10 to be moved to the configuration as illustrated in Figure 4, in which the flow ports 18 are closed but the restriction 42 is open, such that fluid may once more pass through the string.

In use, if the restriction 60 is pumped through the string, it is likely that the tool 10 will move almost immediately to the configuration of Figure 4, due to the force with which the restriction 60 will land on the sleeve 22. However, in other instances, increasing the pump rate at surface will normally be sufficient to move the tool 10 to the Figure 4 configuration.

If the pumps are subsequently switched off again, the spring 52 will move the valve element 48 upwardly to close the restriction 42, and the spring 28 will lift the sleeve 22 to the open position, as illustrated in Figure 5.

From the tool configuration of Figure 5, pumping at lower flow rates will not provide a sufficient differential pressure force across the choke 64 to compress the spring 28, such that the tool 10 may again function as a low flow rate bypass tool. However, increasing the pump rate will return the tool 10 to the Figure 4 configuration.

This embodiment of the present invention is particularly useful in spotting LCM in that, when the ports 18 are open, there is no sump of fluid below the ports 18, such that all of the LCM may be flushed from the tool 10 before the bore below the tool 10 is reopened. Thus, no LCM will be washed into the BHA, where the LCM might otherwise plug the BHA.

Reference is now made to Figure 6 of the drawings, which shows the tool 10 and restriction 60 being used in combination with an alternative body bore restriction

70 which provides a fixed flow restriction. This combination of elements is useful when it is desired to open the flow ports 18 while maintaining fluid circulation through the BHA. To this end, the restriction 70 comprises a tubular body 72 which accommodates a choke 74.

Reference is now made to Figure 7 of the drawings, which illustrates the tool combination of Figure 6 in a locked closed configuration. This is achieved by pumping a valve locking sleeve 76 from surface, which sleeve 76 includes a choke 78 and external sprung fingers 80. The sleeve 76 is dimensioned such that, by deflecting the spring fingers 80 radially inwardly, a lower portion of the sleeve may pass through a sleeve-retaining ring 82 in the body 12 and push the sleeve 22 to the closed position. Once the fingers 80 have passed through the ring 82, the fingers 80 spring outwardly to prevent retraction of the sleeve 76. The valve sleeve 22 is thus locked in the closed position, irrespective of the flow rate of fluid through the tool 10.

Reference is now made to Figures 8a and 8b of the drawings, which illustrate a downhole tool 110 in accordance with an alternative embodiment of the present invention. The tool 110 shares a number of features with the tool 10 described above, but is different in a number of respects, as will be described. The tool 110 features a valve sleeve 122 which is normally biased towards an open position by a compression spring 128, however the sleeve 122 is initially retained in the closed position, as illustrated in Figure 8a, by shear pins 132. Furthermore, the tool 110 is intended to operate using only a single restriction 160, which is illustrated in Figure 8 just before the restriction 160 engages landing sleeve 190. Thus, the restriction 170 does not land directly on the upper end of the sleeve 122. The interaction between the valve sleeve 122 and the landing sleeve 190 is via a cam track 192 formed on the outer face of the sleeve 190 co-operating with cam follower pins 194 extending radially inward from

the upper end of the sleeve 122. The form of the cam track 192 is illustrated in Figure 8b of the drawings. The landing sleeve 190 is normally urged upwards relative to the tool body 112 by a spring 196, such that in the absence of external forces the pins 194 will tend to occupy positions towards the lower end of the cam track 192, as illustrated in Figure 8b.

On the restriction 160 landing on the sleeve 190, the relative positioning of the pins 194 on the cam track 192, as illustrated in Figure 8b, allows the landing sleeve 190 to move downwards and also rotate, such that the pins 194 move towards position 194a. The sleeve 190 is thus able to move relative to the valve sleeve 122 and bottoms out on a body shoulder 198 such that, initially at least, there is no movement of the valve sleeve 122. However, if the pumps are stopped and then started again, this will move the follower pins 194 to the position indicated by numeral 194b on Figure 8b. In this configuration, the axial force created by the pressure differential across the choke 164 will be transmitted from the restriction 160 to the landing sleeve 190 and then to the valve sleeve 122. The force is sufficient to shear the pins 132, such that when the pumps are switched off again, the valve sleeve spring 128 will lift the sleeve 122 to align the flow ports 126, 118.

Of course the tool 110 may be configured such that the follower pins 194 are initially at position 194c on the cam track 192, such that the follower pins 194 move immediately to position 194b as the landing sleeve 190 moves downwards. This would result in the pins 132 being sheared immediately the restriction 160 lands on the sleeve 190.

When the pumps are switched on once more, the cam pins 194 may move along the cam track 192 towards position 194a. Again, in this configuration, the landing sleeve 190 will land out on the body 112 before applying any substantive

force to the sleeve 122, such that the ports 118 will remain open. This contrasts with the first described embodiment in which, once the restriction 60 is in place, anything other than a relatively low flow rate will cause the ports 18 to close.

It will of course also be noted that the tool 110 does not close the bore below the tool 110, such that, even while the ports 118 are opened, fluid may still circulate through the string below the tool 110.

It will be apparent to those of skill in the art that the above-described embodiments provide numerous advantages over previous proposals for flow activated bypass tools.

Furthermore, it will be apparent to those of skill in the art that the above embodiments are merely exemplary of the present invention, and that various modifications and improvements may be made thereto without departing from the scope of invention. For example, the valve sleeve may be coupled to the valve body via a cam arrangement, such that the movement of the valve sleeve relative to the body may be subject to a degree of control.